CSIR-NLC MOBILE LIDAR FOR ATMOSPHERE REMOTE SENSING

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ABSTRACT

A mobile LIDAR (LIght Detection And Ranging) system is being developed and employed for atmosphere remote sensing at the Council for Scientific and Industrial Research (CSIR) National Laser Centre (NLC), Pretoria (25.45 S; 28.16 E), South Africa. In this paper, we describe the results obtained using the CSIR-NLC mobile LIDAR in a 23 hour field campaign at the University of Pretoria.

Index Terms— Atmospheric measurements, Remote sensing, Aerosols, Air pollution, Meteorology

1. INTRODUCTION

Remote sensing is a technique to measure, observe or monitor a physical process or object from a distance. Because remote sensing instrumentation does not make contact with the process or object being observed, the technique allows for (1) measurements without causing significant disturbances, (2) probing large volumes economically and quickly. Atmosphere remote sensing includes spatial and temporal measurements of aerosols, air pollution, weather, agricultural activities, environmental impacts, solar and terrestrial systems, ocean and land surface roughness and large-scale geographical features. The laser radar, more popularly known as LIDAR, is an active remote sensing device that has become a valuable technology for monitoring the atmosphere over a relatively short period of time (for a few seconds to minutes). Furthermore, the interpretation of measurements can accurately reflect the state of atmosphere at the time of the measurements. These systems are currently operational and are used for studying atmospheric structure and dynamics (including turbulence), trace constituents, aerosols, clouds as well as the boundary layer and other meteorological applications. LIDARs are used extensively all over the globe to study aerosols/clouds (Mie Scattering), atmospheric density and temperature (Rayleigh Scattering), metallic ion species (Resonance Scattering), minor constituents and trace gases (Differential absorption), composition (Raman Scattering) and winds (Doppler LIDAR).

Figure 1: LIDAR measurements at University of Pretoria

More recently, the CSIR National Laser Centre and the Department of Geography, Geoinformatics and Meteorology at the University of Pretoria (UP) have embarked on a project involving specialized laser research into atmospheric remote sensing using LIDAR. The initiative forms part of the Southern Education and Research Alliance (SERA) which seeks to create the education, research and technology transfer infrastructure and competence needed to significantly contribute to South Africa's global competitiveness.

A 24 hour LIDAR experiment was planned at University of Pretoria on 16-17 October 2008 to obtain a better understanding of the atmosphere boundary layer evolution and aerosol (solid particles suspended in the air) concentrations. The experimental data was collected over 23 hours from 16 October, 16h00 to 17 October 15h00. The study further addresses the level of mixing of different chemicals (pollutants) emitted by various sources over Pretoria. In this paper, we present the results obtained from the above experiment and interpret through back-trajectory air mass transport model.

2. CSIR-NLC MOBILE LIDAR SYSTEM

The LIDAR system comprises a laser transmitter, optical receiver and a data acquisition system. The complete LIDAR system is custom fitted into a van using a shock absorber frame. Hydraulic stabilizer feet have been added to the vehicle suspension to ensure stability during measurements. A Nd:YAG laser is used for transmission which is presently employed at the second harmonic (532 nm) at a repetition rate of 10 Hz. The receiver system employs a Newtonian telescope configuration with a 16 inch primary mirror. The backscattered signal is subjected to fall on the primary mirror of the telescope and is then focused to a plane mirror kept at an angle of 45 degrees. It is detected by the Photo-Multiplier Tube (PMT) and the PMT output is transmitted to the transient digitizer and computer for further analysis and data archival. The data acquisition is performed by a transient recorder which communicates with a host computer for storage and offline processing of data [1].

3. RESULTS

Figure 2 illustrates the obtained LIDAR backscatter measurement for the 23 hours of observation at University of Pretoria. The first two colour maps show the analog and photon count data which is measured directly from the LICEL transient recorder. The analog and photon count signals are merged appropriately and the resultant glued photon count is shown in the third colour map. More details about the gluing methodology described in Sharma et al., 2009, [2]. Figure 3 shows the presence of low level cloud from 23:00 hrs to 02:00 hrs and over the height region from 3.8 km to 5.5 km and for longer than 3 hours. Other than the cloud structure, the aerosol structure evidences the temporal evolution of planetary (nocturnal) boundary layer (PBL). The PBL is found to be around 2 km and found to vary with time, during night it is found to be more stable and vary largely over day time. It is expected that during night, where there is no solar input, the aerosols are usually non-reactive and are found to be stable in comparison to the day time.

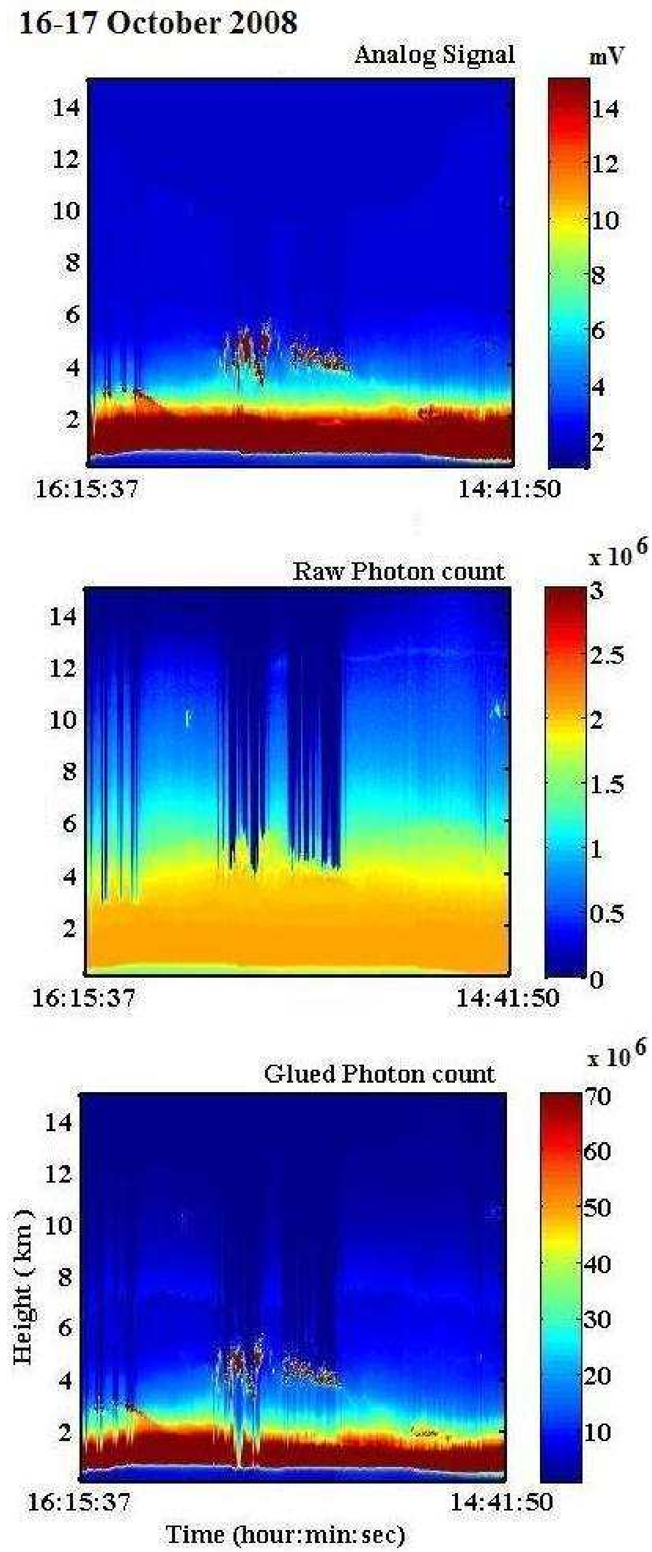

Figure-2: Height-time-colour map of LIDAR signal returns for 16-17 October 2008

In order to study the air mass, transport/source back-trajectory models were run for different time of LIDAR measurements. Back-trajectory analyses were conducted using the National Oceanographic and Atmospheric Administration's (NOAA), Air Resources Laboratory (ARL), online version which run interactively on the web through the READY system (http://www.arl.noaa.gov/ready.html), HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model access via NOAA ARL READY website (http://www.arl.noaa.gov/ready/hysplit4.html) [3]; [4]). The HYSPLIT model is a useful tool for computing simple air parcel trajectories to complex dispersion and deposition simulations which is developed by NOAA. HYSPLIT backward trajectory analysis is also used to understand synoptic-scale, atmospheric transport and identify the most probable sources of pollutants for selected site, one at particular time and direction, compared to an alternate source in another direction. The HYSPLIT model calculates air mass position over time using pressure, temperature, wind speed, vertical motion and solar radiation inputs. These inputs were entered into the HYSPLIT model using the NOAA, Global Data Assimilation System (GDAS) meteorological database for each trajectory calculation. Air mass position history was computed within HYSPLIT by a Lagrangian three dimensional air mass velocity algorithm that has been used for atmospheric trajectory analysis for several decades [5].

Back trajectory analyses were performed for a time period of ~24 h of the LIDAR measurement at University of Pretoria, Pretoria (25.45°S; 28.13°E). Here, we have illustrated two different conditions of the above mentioned 23 hours LIDAR measurements. One each illustrates during the passage of cloud over site (Figure 3a) and the other during the presence of only aerosol (Figure 4a). Figures 3b and 4b respectively describe the back trajectory results obtained during 24:00-01:00 hrs (local time, UT+2 hrs) and 10:00-11:00 hrs of 17 October 2008 and for three different height levels, 2 km, 2.5 km and 3 km (different colored lines in the figure). LIDAR measurements during 24:00-01:00 hrs illustrate the presence of low level cloud in the height region between 4 km and 5 km in addition to fluctuating boundary layer heights due to the turbulent aerosol structure. Since the LIDAR measurements are performed during the night, the solar input for such a fluctuating boundary layer is considered to be negligible. Meridional mass transports to Pretoria may have influenced such fluctuations which is evident from the back-trajectory analysis (see. Figure 3b). Figure 3b illustrates that there is an air-mass transport from Botzwana over the height region from 2 km to 3 km. We also found the air-mass transport for the lower height region (less than 2 km) from Zimbabwe; in addition to the internal recirculation of air within South Africa, while the upper height region (above 3 km) shows the air mass transport from Namibia and Botswana (figures are not shown).

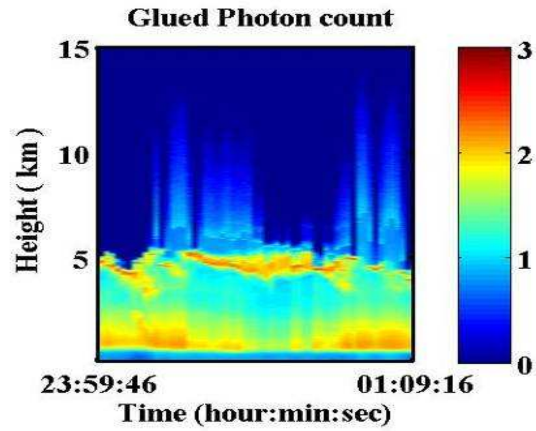

Figure 3a: Height-time-colour map of LIDAR backscattered signal, expanded view of Figure-2 for a particular one hour time period.

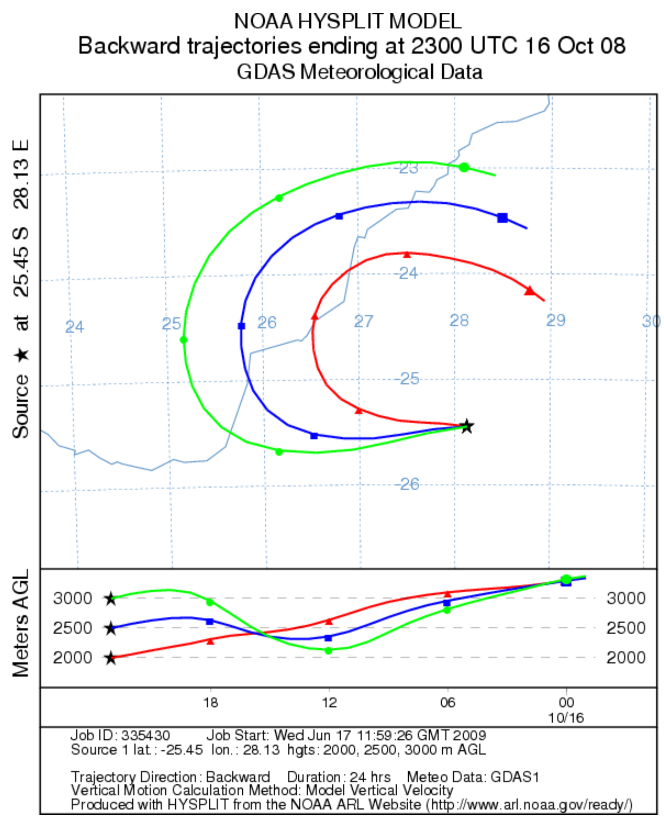

Figure 3b: 24 hrs HYSPLIT backward trajectory results for the LIDAR measurement illustrated in Figure 3a.

We have also performed the similar study for cloud free LIDAR observations from 10:00 – 11:00 hrs of 17 October 2008 (see Figure 4). It is noticeable from Figure 4a that the boundary layer is stable without much fluctuation in the backscatter signal intensity. The stable layer is extended for the upper height regions (above 3 km). In this case study, the back-trajectory was analysis performed for the same height levels as above (2 km, 2.5 km and 3 km) and shown in Figure 4b. The trajectory analysis shows the air mass transport originated from different source

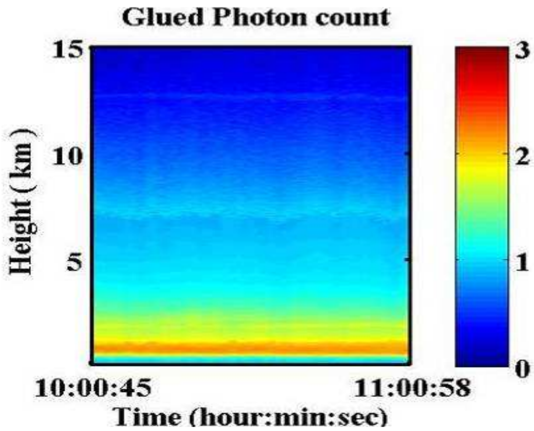

Figure 4a: Same as Figure-3(a) but for the time period of 10:00 – 11:00 of 17 October 2008.

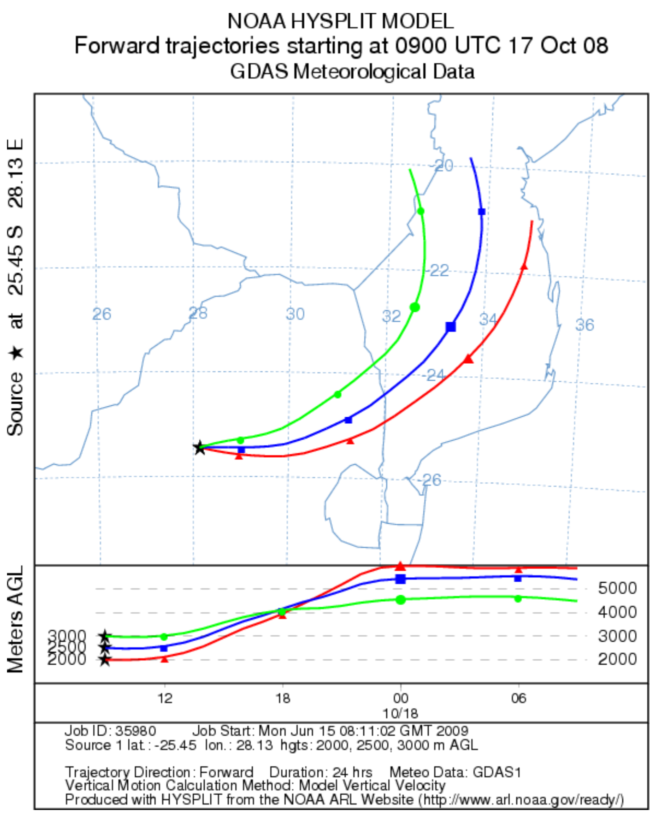

Figure 4b: 24 hrs HYSPLIT backward trajectory results for the LIDAR measurement illustrated in Figure-4a.

regions and is different for different heights. The height region from 2 km to 3 km shows the mass transports mainly from Mozambique while the heights between 3.5 km and 4.5 km shows the transport from Namibia to Pretoria passing through Botswana. The stable boundary layer height might be due to the above mixture of transport of air masses, except that in this case it has originated from one source region, in comparison to the earlier observation which has multiple source regions.

The HYSPLIT model also provides the vertical transport from one region to another which allows us to study the atmosphere vertical exchange process in addition to the horizontal/meridional exchanges. Thus, the LIDAR observations incorporated with the backward trajectory analysis allows us to interpret the air-mass transport (both vertically and horizontal) and this can be used for identifying the exact source regions (even for pollutant transports).

4. ACKNOWLEDGEMENTS

We are thankful to the different South Africa funding agencies in addition to the Council for Scientific and Industrial Research-National Laser Centre (CSIR-NLC), Department of Science and Technology (DST), National Research Foundation (NRF) (Grant no: 65086), African Laser Centre (ALC), Centre National de la Recherché Scientifique (CNRS) (France), French Embassy in South Africa (France) and Southern Educational Research Alliance (SERA). The authors gratefully acknowledge the NOAA Air Resources Laboratory (ARL) for the provision of the HYSPLIT transport and dispersion model and/or READY website (http://www.arl.noaa.gov/ready.html) used in this publication.

5. REFERENCES

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